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World records in half-marathon

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Abstract

The relationship between age and elite marathon race times is well investigated, but little is known for half-marathon running. This study investigated the relationship between half-marathon race times and age in 1-year intervals by using the world singe age records in half-marathon running and the sex difference in performance from 5-91 years in men and 5-93 years in women. We found a 4^{th} order-polynomial relationship between age and race time for both women and men. Women achieve their best half-marathon race time earlier in life than men, 23.89 years compared with 28.13, but when using a non-linear regression analysis, the age of the fastest race time does not differ between men and women, 26.62 years in women and 26.80 years in men. Moreover, women increase the sex difference in half-marathon running performance to men with advancing age.

Key words: female, male, aging, youth, performance

Introduction

It is well known that marathon running still has an unbroken high level of popularity. However, more people run a half-marathon than a marathon in the USA. In 2016, a total of 1,900,000 runners finished a half-marathon which is a little bit less than the 1,986,600 finisher in 2015 and the record of more than 2,000,000 finishers in 2014. In contrast to marathon races, the number of half-marathons increased to 2,800 races in 2016 from 2,700 races in 2015 (www.runningusa.org/half-marathon-report-2017).

Little is known for the age-related performance decline in both marathon and half-marathon running. When 300,757 runners were analyzed in 10-year age group intervals (*i.e.* six decades, 20-79 years), mean marathon and half-marathon times were virtually identical for the age groups from 20-49 years (Leyk et al., 2007). However, most probably, the age-related performance decline is different between female and male half-marathoners. A very recent study investigated the age-related decline in 5-year age group intervals in half-marathoners competing in the 'GöteborgsVarvet', in the largest half-marathon in the world. In that race, women achieved the fastest race time at an earlier age compared to men where the fastest race times were observed in women in age groups <35 and 35-39 years and in men in age group 35-39 years (Knechtle & Nikolaidis, 2018).

However, the age of peak performance has been well investigated in marathon running and has been reported to lie at ~25-35 years for both women and men depending upon nationality and performance level of the athletes (Aschmann et al., 2013; Hunter, Stevens, Magennis, Skelton, & Fauth, 2011; Knechtle, Aschmann, et al., 2017; Knechtle, Assadi, Lepers, Rosemann, & Rust, 2014; Lara, Salinero, & Del

Coso, 2014; Lehto, 2016; Nikolaidis, Onywera, & Knechtle, 2016). It has been shown that East-African runners were the youngest and the fastest (Aschmann et al., 2013; Knechtle, Nikolaidis, Onywera, et al., 2016) and their age is at (mean±sd) 29.7±4.0 years for Kenyan women, 28.9±4.2 years for Kenyan men, 25.7±3.8 years for Ethiopian women and 26.7±3.8 years for Ethiopian men (Nikolaidis et al., 2016).

Men seem to achieve their best marathon race time at an earlier age than women. When running times of the top ten women and men at 1-year intervals from 18 to 75 years in the 'New York City Marathon' were analyzed for the 2010 and 2011 races the fastest race times were obtained at 27 years in men and at 29 years in women (Lara et al., 2014). However, when the performance of the world's best runners in the 10-km, half-marathon, marathon, and 100-km races by age, sex, and nationality during the period 1999-2015 were analysed, women (29.5±5.5 years) were significantly older than men (29.1±4.3 years) in marathon running (Knechtle, Nikolaidis, Onywera, et al., 2016).

In half-marathon running, little is known for the age of peak performance. A study determined in 125,894 female and 328,430 male half-marathoners competing between 1999 and 2014 in all half-marathons held in Switzerland the age of the finishers and found that women (41.4±10.6 years) were at the same age than men (41.3±10.3 years) (Knechtle, Nikolaidis, Zingg, Rosemann, & Rust, 2016). However, when the performance of the world's best runners in the 10-km, half-marathon, marathon, and 100-km races by age, sex, and nationality during 1999-2015 were analysed, women (27.5±4.7 years) were older than men (25.9±4.1 years) in half-marathon (Nikolaidis et al., 2016). The ages were for East-African runners 27.2±3.9 years for Kenyan women and 25.8±6.1 years for Kenyan men and 24.5±3.6 years for Ethiopian women and 24.9±4.2 years for Ethiopian men (Nikolaidis et al., 2016).

These findings let assume that for half-marathon running a difference in the age of peak performance compared to marathon running exists and also a difference in the age of peak performance between women and men. In order to elucidate these situation, we investigated the relationship between half-marathon race times and age in 1-year intervals by using the world singe age records in half-marathon running and the sex difference in performance from 5-91 years in men and 5-93 years in women. Based upon existing findings we hypothesized to find a U-shaped quartic polynomial relationship between age and half-marathon running performance with an increasing difference between women and men.

Methods

Ethics

This study was approved by the Institutional Review Board of St. Gallen, Switzerland, with a waiver of the requirement for informed consent given that the study involved the analysis of publicly available data.

Data sampling and data analysis

The data set for this study was obtained from the website of the 'Association of Road Racing Statisticians' (ARRS) www.arrs.net/SA_HMar.htm. We analysed world single age records in half-marathon running, during 1977 – 2017, for women and men from the age of 5 to 91 years for men and from the age of 5 to 93 years for women, respectively. Criteria for inclusion are described in the ARRS website www.arrs.net. In particular, performances were subject to the same standards as listing for national records plus the additional requirement that the runner's date of birth (as well as the race date) must be known. Therefore we have the runner's exact age at the time of the performance. Single age records that meet the ARRS qualifying standards may be expected to be fairly reliable. At older (and younger) ages, the best marks known to ARRS are listed.

Statistical analyses

The acceptable type I error was set at $p<0.05$. All data are presented as means and standard deviations. Time was recorded in the format "hours:minutes:seconds". All statistical analyses were carried out using statistical package R, R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

For data visualization, we use ggplot2 package. Percentage sex difference in race time was calculated using the formula 100×(women's race time-men's race time)/men's race time. The age of peak performance was the age at which we have a minimum on the time-fitted value from a non-linear regression model with a fourth order (*i.e.* quartic) polynomial function, $y=ax^4+bx^3+cx^2+dx+e$. Since we have repeated measurements within runners, we performed a mixed model, using R packages lme4 and lmerTest. Age, gender and their interaction, were considered as fixed effects, runners as random effects of intercepts. In this way, we corrected for correlated observations of the same runner.

Results

Overall, we had 170 observations, 87 (51%) men records and 83 (49%) women records. Runners were 109, 53 (49%) men and 56 (51%) women. Therefore we have repeated measurements within runners recorded at different age. Overall the average was 1.56 per runner, but in fact only 27 (25%) runners have more than one record. Martin Rees (WAL) had 11 reported records, the maximum number per runner, as shown in Appendix (Figure A.1) where we reported trend performance for runners with more than one record. In Table 1 we reported participation and performance, overall by gender and age. P-value of T-test for performance between genders is reported. Age was grouped in 7 categories. We observe that gender was quite equally represented overall and in each age group, except age [75, 94) where women were 43% of the total age group. Instead age [30-40) had a number of women greater than the number of men, that is women were 53% of the total age group. Overall, men performance was 01.21.46 ± 00.29.32, not significantly different ($p=0.103$) from women performance 01.29.32 ± 00.32. Instead, performance at different ages was significantly different between gender, except for extreme ages, youngers 5-19, $p=0.922$, and olders 75-93, $p=0.240$. If we consider overall performance by sex, corrected for repeated measurement, not shown in Table 1, we have 01:22:33 ± 00:31:10 for men and 01:27:24 ± 00:34:33 for women, $p=0.444$. In men, the youngest half-marathoner was Matthews Feibush (USA) who completed in May 2013 at the age of 5.88 years a half-marathon in 03:02:57.5 h:min:s. The oldest half-marathoner was Mike Fremont who finished in April 2013 at the age of 91.18 years in 03:06:23 h:min:s. In women, Nasiy Jobe (USA) completed in October 1984 a half-marathon in 01:51:31 h:min:s at the age of 5.90 years as the youngest female half-marathoner. The oldest female half-marathoner is Gladys Burrill (CAN) who finished in March 2012 at the age of 93.36 years the half-marathon in Honolulu in 04:49:05 h:min:s.

The fastest half-marathon race times were achieved by Zersenay Tadese (ERI) in 2010 in 00:58:23 h:min:s at the age of 28.13 years in men and Joyciline Jepkosgei (KEN) very recently in 2017 in 01:04:51 h:min:s at the age of 23.89 years in women.

We found a U-shaped quartic order relationship between age, as a continuous variable, and race time for both women and men (Figure 1). In Table 2 we reported fixed effect estimate coefficients of our mixed effect model. All effects were significant, even interaction term between age and sex. Intraclass Correlation Coefficient (ICC) which is a measure of how strongly units in the same group resemble each other was high: 0.96. This justify the use of a mixed model with one random effect of intercept for each runner. In Appendix, Figure A.2, random effects of intercepts are plotted for each runner. From Figure 1, we can see that the age of the fastest race time was 26.62 years in women and 26.8 years in men. To see how the "tails" of the age distribution influence the estimated regression parameters, we considered a separate regression analysis for age 20-60. Results are shown in Appendix, Table A.1 and Figure A.3. According to this model, the age at the best performance was 26.44 for men and 27.17 for women. The sex difference in performance increased largely across years (Figure 2). We also found, but we did not show in table, that the fastest top ten results occurred in the last ten years, 2007-2017. Their range was 01:04:51 - 01:06:07, mean = 01:05:34 for women and 00:58:23 - 00:58:58, mean = 00:58:43 for men.

It is beyond our main aim to investigate performance at the time it was set and nationality of runners. However, we reported in Table 3 participation and performance, overall by period and age. P value of T-test for performance between sex is reported. We noticed that performance is significantly different, p=0.004, only during period 2007-2012, with 01.09.15 ± 00.13.41 for men and 01.26.59 ± 00.20.25 for women. We found, but we did not show in tables, that we have a relevant difference, between gender, for runners coming from Canada, 9 women and 10 men. This was due mostly for a high variability within women. In fact we have 02.26.20 ± 00.56.01 for women and 01.32.52 ± 00.10.38 for men.

Discussion

This study investigated the relationship between half-marathon race times and age in 1-year intervals by using the world singe age records in half-marathon running with the hypothesis to find a U-shaped relationship between age and half-marathon running performance with a difference between women and men. Indeed, we found a U-shaped relationship between age and race time for both women and men where the age of the fastest race time was 26.62 years in women and 26.8 years in men. A second important finding was that the sex difference in performance increased largely across years.

Women achieve peak half-marathon performance at near the same age as men

An earlier age of peak performance in half-marathon running could be assumed by very recent findings of the age-related performance decline in half-marathon running. In the 'GöteborgsVarvet', in the largest half-marathon in the world, women achieved the fastest race time in age groups <35 and 35-39 years and men in age group 35-39 years (Knechtle & Nikolaidis, 2017). We found, however, that women achieve their best half-marathon race time at a similar age like men.

Different findings have been reported for marathon running for the age of peak performance in female and male marathoners. When the age at time of competition and the running times of the first five placed male and female runners who competed in the seven marathons of the World Marathon Majors Series were analyzed, women (29.8±4.2 years) were older than men (28.9±3.8 years), but for only two of the seven marathons, the Chicago and the London marathons. There was no sex difference in age for the Berlin, Boston, New York City, World Championship, and Olympic marathons (Hunter et al., 2011). When the age of peak marathon performance was investigated in female and male marathoners competing in two large city marathons held in Switzerland, the fastest man was ~23.7 years old and the fastest woman ~32.2 years old. When all finishers were considered in 1-year age intervals, the fastest men were ~35.0 years old and the fastest women ~33.8 years old (Knechtle, Nikolaidis, Zingg, Rosemann, & Rust, 2017). These disparate findings for female and male marathoners are most likely explained by the different performance levels of the athletes and the kind of the statistical analysis.

Women increase the sex difference to men with increasing age

The second important finding was that the sex difference in performance increased largely across years. To date, it is well known that the sex difference in marathon running increases with increasing age (Senefeld, Joyner, Stevens, & Hunter, 2016). When running times of the first 10 placed men and women competing in the 'New York City Marathon' between 1980 and 2010 in 5-year age group intervals between 20 and 79 years and the number of men and women were analyzed, the sex difference increased with advanced age and decreased across the 31 years, but more for the older age groups (Hunter & Stevens, 2013).

However, there seem to exist differences between sports disciplines such as running and swimming where the sex difference in swimming increased with world record place and age, but was less than for marathon running (Senefeld et al., 2016). Recent studies investigating age group swimmers in pool swimming in freestyle (Knechtle, Nikolaidis, Konig, Rosemann, & Rust, 2016), butterfly (Knechtle, Nikolaidis, Rosemann, & Rust, 2017b), individual medley (Nikolaidis & Knechtle, 2017), backstroke (Unterweger, Knechtle, Nikolaidis, Rosemann, & Rust, 2016), and breaststroke (Knechtle, Nikolaidis, Rosemann, & Rust, 2016) as well as open-water swimmers in 3,000 m (Knechtle, Nikolaidis, Rosemann, & Rust, 2017a) showed that men were not faster than women in all age groups. Regarding elite age group swimmers competing in the FINA World Championships, the distance and the discipline seems to influence the sex difference. In backstroke swimmers from 50 m to 200 m, men were faster than women in age groups 25-29 to 80-84 years, but not in age groups 85-89 to 95-99 years (Unterweger et al., 2016). In freestyle swimming from 50 m to 200 m, men were faster than women in age groups 25-29 to 80-84 years, but not in age groups 85-89 to 95-99 years (Knechtle, Nikolaidis, Konig, et al., 2016). In breaststroke swimming from 50 m to 200 m, women reduced the gap to men between ~40 and ~75 years, but not in younger (<40 years) or older (>75 years) age groups (Knechtle, Nikolaidis, Rosemann, et al., 2016). In 3,000 m freestyle in age groups swimmers in age groups 25-29 to 85-89 years, women were slower in age groups 25-29 to 70-74 years. In age groups 75-79 and 85-89 years, however, race times were similar for both women and men (Knechtle, Nikolaidis, Rosemann, et al., 2017a). In individual 200m and 400m medley, men were faster than women from 25-29 to 80-84 years, but not from 85-89 to 90-94 years (Nikolaidis & Knechtle, 2017). In butterfly swimming from 50 m to 200 m, women were not slower compared to men in the master group 90-94 years; moreover, women reduced the gap to men between ~30 and ~60 years, although not in younger or older master groups (Knechtle, Nikolaidis, Rosemann, et al., 2017b).

Interpretation of findings by a physiological point of view

The increase of race time in half-marathon records with aging was in agreement with the changes of physiological correlates of this sport across life-span. Actually, in addition to anthropometry and training characteristics (Rust et al., 2011), the race time in half-marathon has been shown to relate with maximal oxygen uptake (VO_2max), speed at the anaerobic threshold and maximal aerobic speed (Gomez-Molina et al., 2017). VO_2max in endurance exercise trained athletes was 25-32% lower than their counterparts younger by three-to-four decades (Ogawa et al., 1992). Furthermore, the sex difference in performance in half-marathon should be attributed partially to differences in VO_2max, *e.g.* men endurance runners had 10% higher value than their women counterparts (Helgerud, 1994). With regards to the increase of sex difference in half-marathon performance with aging, this observation should be interpreted in terms of participation (increase of the men-to-women ratio with increasing age) (Knechtle, Nikolaidis, Zingg, et al., 2016) rather than sex difference in changes of physiological characteristics across the life-span.

Conclusions

In the world singe age records in half-marathon running performance from 5-91 years in men and 5-93 years in women, the age of the fastest race time is 26.62 years in women and 26.8 years in men. The sex difference in performance increased largely across years. Women seem to achieve the best half-marathon race time at the same age as men and increase the sex difference in performance with advancing age.

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Table 1. Participation and performance overall, by gender and age.

	Gender	N (%)	Mean (time)	Sd	P (t.test mean)
Overall	Men	87 (51%)	01.21.46	00.29.32	0.103
N=170	Women	83 (49%)	01.29.32	00.32.06	
Age					
[5,20)	Men	15 (50%)	01.26.54	00.32.50	0.922
	Women	15 (50%)	01.27.56	00.23.50	
[20,30)	Men	10 (50%)	00.58.46	00.00.15	<0.001
	Women	10 (50%)	01.05.53	00.00.45	
[30,40)	Men	9 (47%)	00.59.38	00.00.38	<0.001
	Women	10 (53%)	01.07.05	00.01.18	
[40,50)	Men	11 (52%)	01.04.16	00.02.05	<0.001
	Women	10 (48%)	01.12.08	00.02.07	
[50,60)	Men	10 (50%)	01.10.37	00.02.14	<0.001
	Women	10 (50%)	01.20.42	00.03.35	
[60,75)	Men	15 (50%)	01.19.44	00.06.01	<0.001
	Women	15 (50%)	01.35.06	00.07.16	
[75,94)	Men	17 (57%)	02.02.09	00.32.27	0.240
	Women	13 (43%)	02.20.38	00.47.10	

Table 2. Non-linear regression analysis (mixed model) of world records by sex, age and their interaction. Men is the reference gender group.

Fixed effects	**Estimate**	**Std. Error**	**p**
intercept	0.05641	0.00112	< 0.001
gender=Women	0.00767	0.00155	< 0.001
a(age)	0.09678	0.01126	< 0.001
b(age^2)	0.15832	0.00927	< 0.001
c(age^3)	-0.03585	0.00797	< 0.001
d(age^4)	0.08633	0.00893	< 0.001
Women*a(age)	0.07756	0.01789	< 0.001
Women*b(age^2)	0.03810	0.01517	0.013
Women*c(age^3)	0.03620	0.01266	0.005
Women*d(age^4)	-0.00741	0.01299	0.570

ICC=0.96

Table 3. Participation and performance overall, by sex and period when record was set.

Year	Gender	N (%)	Mean	Sd	p
[1977,1997)	Men	13 (59%)	01.19.14	00.17.28	0.617
N=22	Women	9 (41%)	01.22.39	00.13.59	
[1997,2007)	Men	19 (64%)	01.14.29	00.12.19	0.123
N=29	Women	10 (34%)	01.26.09	00.20.27	
[2007,2012)	Men	18 (49%)	01.09.15	00.13.41	0.004
N=37	Women	19 (51%)	01.26.59	00.20.25	
[2012,2017]	Men	37 (45%)	01.32.29	00.39.54	0.976
N=82	Women	45 (55%)	01.32.45	00.40.02	

Table A.1 Non-linear regression analysis (mixed model) of world records by sex, age, 20-60, and their interaction. Men is the reference sex group. We have n=80 observations and 53 runners.

Fixed effects	**Estimate**	**Std. Error**	**p**
intercept	0.044056	0.000106	< 0.001
gender=Women	0.005604	0.000146	< 0.001
a(age)	0.028610	0.000926	< 0.001
b(age^2)	0.008929	0.000857	< 0.001
c(age^3)	0.001954	0.000825	0.020
d(age^4)	0.001330	0.000811	0.105
Women*a(age)	0.006911	0.001274	< 0.001
Women*b(age^2)	0.005355	0.001215	< 0.001
Women*c(age^3)	0.001891	0.001212	0.124
Women*d(age^4)	0.001932	0.001185	0.107

Legends of figures

Figure 1 World record in half-marathon by sex and age, in years. Points are observations. Curves represent quartic degree polynomial regression. Vertical dashed line is the age at peak performance.

Figure 2 Sex difference by age in years. For each age group, sex difference was calculated as 100 × (women's mean race time - men's mean race time) / men's mean race time. The line represents fitted value from model in Figure 1.

Figure A.1 Trend performance for runners with more than one record.

Figure A.2 Mixed model: random effects of intercepts, for each runner.

Figure A.3 World record in half-marathon by sex and age, 20 - 60. Points are observations. Curves represent quartic degree polynomial regression. Vertical dashed line are the ages at peak performance.

Figure 1

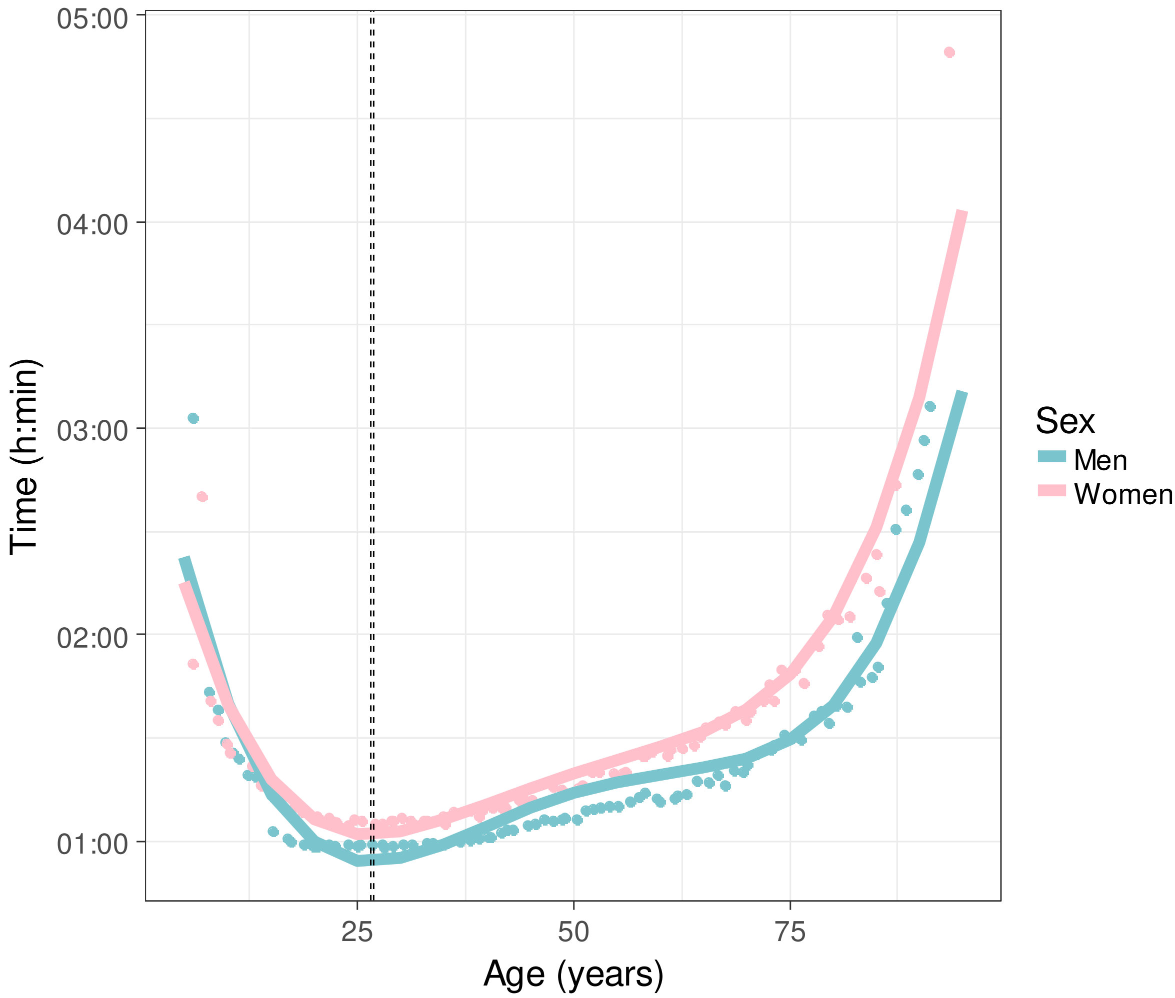

05:00
04:00
03:00
02:00
01:00
Time (h:min)
25
50
75
Age (years)
Sex
Men
Women

Figure 2

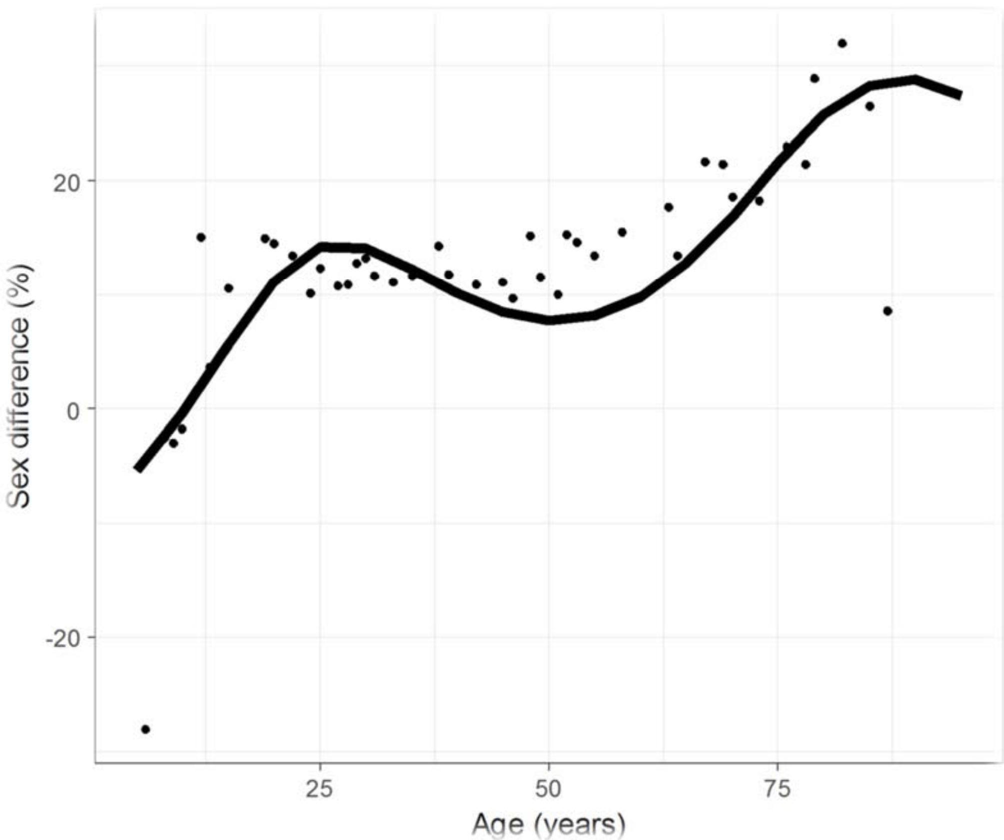
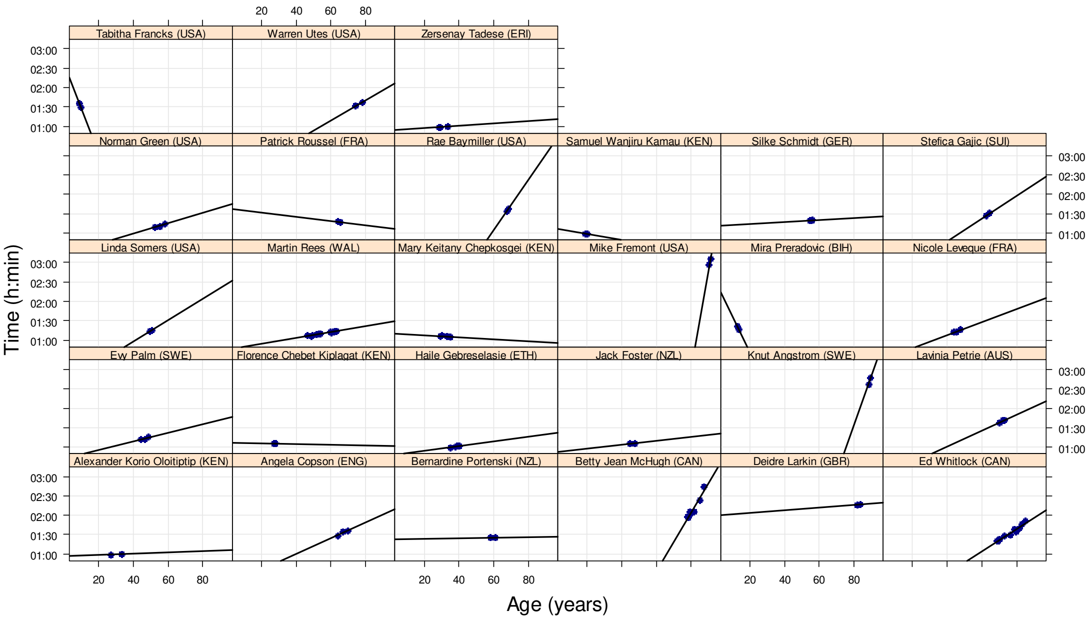


Figure A.1


Tabitha Francks (USA)
Warren Utes (USA)
Zersenay Tadese (ERI)
Norman Green (USA)
Patrick Roussel (FRA)
Rae Baymiller (USA)
Samuel Wanjiru Kamau (KEN)
Silke Schmidt (GER)
Stefica Gajic (SUI)
Linda Somers (USA)
Martin Rees (WAL)
Mary Keitany Chepkosgei (KEN)
Mike Fremont (USA)
Mira Preradovic (BIH)
Nicole Leveque (FRA)
Evy Palm (SWE)
Florence Chebet Kiplagat (KEN)
Haile Gebreselasie (ETH)
Jack Foster (NZL)
Knut Angstrom (SWE)
Lavinia Petrie (AUS)
Alexander Korio Oloitiptip (KEN)
Angela Copson (ENG)
Bernardine Portenski (NZL)
Betty Jean McHugh (CAN)
Deidre Larkin (GBR)
Ed Whitlock (CAN)
Time (h:min)
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02:30
02:00
01:30
01:00
20
40
60
80
Age (years)

Figure A.2

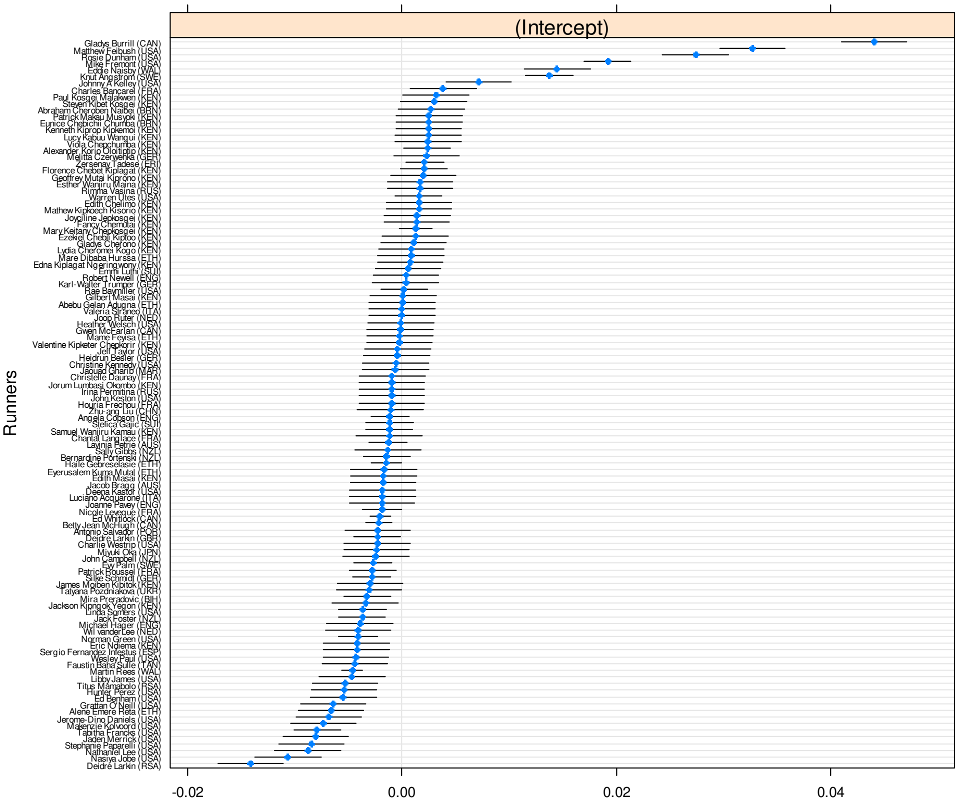

Figure A.3